NOTES
ON
DRAWING

NOTES ON DRAWING

AS APPLIED TO THE

COURSE IN VEHICLE DRAFTING AND CONSTRUCTION

OF

THE CARRIAGE MONTHLY

By

EDWARD E. KRAUSS

B.S. in M.E., University of Pennsylvania

Instructor in Vehicle Drafting and Mechanical Drawing

Central Educational Institute, Philadelphia, Pa.

PUBLISHED BY

WARE BROS. COMPANY

PHILADELPHIA, U. S. A.

1914

THIS BOOK forms part of THE CARRIAGE MONTHLY Course in Vehicle Drafting and Construction, prepared by Chas. A. Heergeist, technical editor of THE CARRIAGE MONTHLY.

PREFACE

THERE has no doubt ofttimes been apparent to teachers of mechanical drawing the need of a booklet giving instructions for the handling of instruments, general data for drawing and a summary of geometrical definitions, which could be placed in the hands of beginners. The present "Notes on Drawing" have been prepared, based on experience in teaching apprentices and mechanics, in an endeavor to supply this need especially in connection with THE CARRIAGE MONTHLY Course in Vehicle Drafting and Construction, prepared by Chas. A. Heergeist, Technical Editor of THE CARRIAGE MONTHLY.

It is desired to make acknowledgment to Wm. C. H. Slagle, Assistant Professor of Drawing, University of Pennsylvania, for helpful suggestions on drawing; to Dr. George H. Hallett, Professor of Mathematics, University of Pennsylvania, for reading the manuscript on Geometrical Definitions; to Chas. A. Heergeist, Technical Editor of THE CARRIAGE MONTHLY, for the preparation of the drawings; and to F. Weber & Company, for the use of some of the illustrations.

E. E. K.

Philadelphia, Pa., January, 1914.

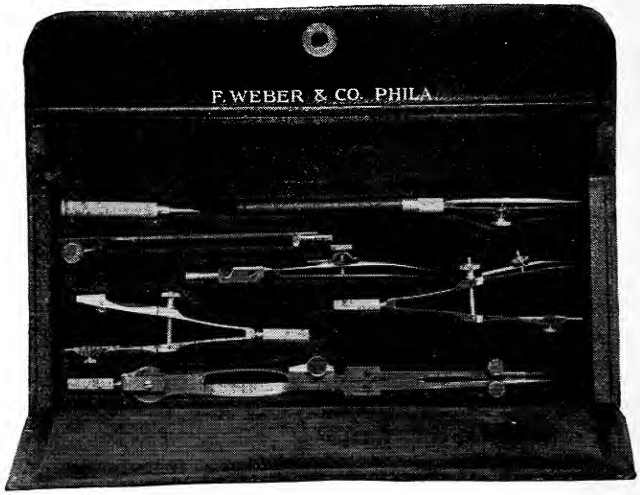


Fig. 1. Drawing Instruments.

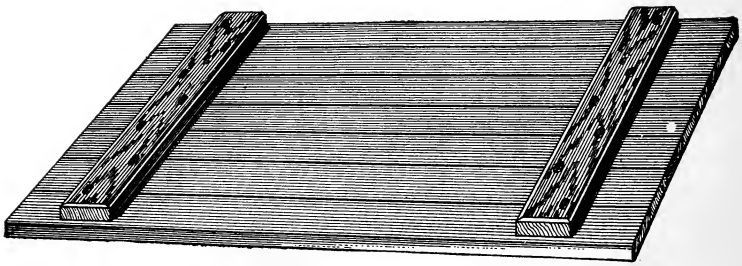


Fig. 2. Drawing Board.

INSTRUCTIONS FOR MAKING DRAWINGS

A drawing is the representation of objects on a plane surface by means of lines. There are "freehand drawings" which are made entirely by hand and "mechanical drawings", made with the aid of instruments. Vehicle drawing is a branch of mechanical drawing.

The Essentials. In making a mechanical drawing the essentials are accuracy, clearness and neatness, as the object of such a drawing is to enable one to make the part or combination pictured, without any other information than that contained on the drawing. The workman constructs as the drawing shows, not as the draftsman may have intended to show.

I. Instruments and Their Use

The following instructions should be carefully studied and kept in mind when making drawings:

1. List of Instruments and Materials.
   - *a.* Drawing board 22 x 30 inches.
   - *b.* Set of drawing instruments in a case, Fig. 1, containing—
     Compass, 4½ in., with pencil and pen attachments, lengthening bar and extra needle point.
     Bow pencil, 3½ in.
     Bow pen, 3½ in.
     Ruling pen, 5 in., with cleaning device.
   - *c.* Triangular boxwood scale, having scales of 4, 3, 2, 1½, 1¼, 1, ¾ and ½ inches to the foot and 50 parts to the inch, divided the full length of the scale.
   - *d.* T-square, 30 in. long.
   - *e.* 45 degree celluloid triangle, 7-in.
   - *f.* 60 degree celluloid triangle, 9-in.
   - *g.* Irregular curve, No. 16, celluloid.
   - *h.* Irregular curve, No. 20, celluloid.
   - *i.* Two 6-H Koh-i-noor drawing pencils.
   - *j.* Emerald pencil eraser.
   - *k.* Cleaning rubber or artgum.
   - *l.* ½ dozen thumb tacks.
   - *m.* Drawing paper, 22 x 30 in.
   - *n.* Lettering paper.
   - *o.* Penholder with cork tip and Falcon pen.

2. Drawing Board. The drawing board, at least 22 in. wide and 30 in. long, should be made of strips of well-seasoned pine, about

1 in. thick, glued together (Fig. 2). Across the back there should be a series of grooves, ½ in. deep, running with the grain of the wood to prevent warping. There should be two ledges of hardwood across the back, held in place by screws in oval slots, to allow for contraction and expansion.

The sides of the board should be perfectly straight and square.

3. DRAWING PAPER. The drawing paper for this course should be cold pressed and smooth. The size is 22 x 30 in., which sheet cut in half will give two sheets 22 x 15 in.

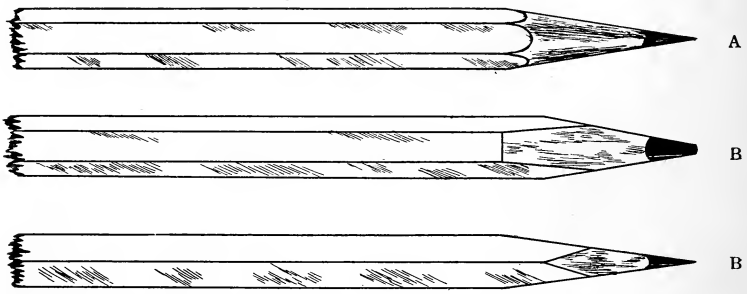


Fig. 3. Method of Sharpening Pencil. A. Conical Point. B. Chisel Point.

To fasten the paper to the board place a thumb tack in the upper left-hand corner of sheet and see that the upper edge of paper is in line with the T-square. Passing the left hand diagonally over the paper from the thumb tack to the lower right-hand corner, thus pulling the paper taut, place a thumb tack in the latter corner. Now fasten the other corners, pulling the paper taut from the center.

4. PENCILS. In order that fine lines may be drawn the lead of the pencil should be hard, 6-H hexagonal generally being used. With such a pencil very fine and clear lines can be made, from which more accurate measurements can be secured than if a softer pencil is used, and, in addition, it lasts longer.

In drawing lines with a pencil always move the hand in a direction away from the body, letting the pencil lean in the direction the hand moves (Fig. 14). The pencil should always be drawn over the paper, not pushed.

Sharpening of Pencils. One pencil should be sharpened to a conical or round point (A) for laying off, and the other to a chisel point (B) (Fig. 3), for drawing lines. To keep the pencil sharp rub the lead on a fine file or a piece of fine emery cloth or sandpaper tacked to a little block of wood.

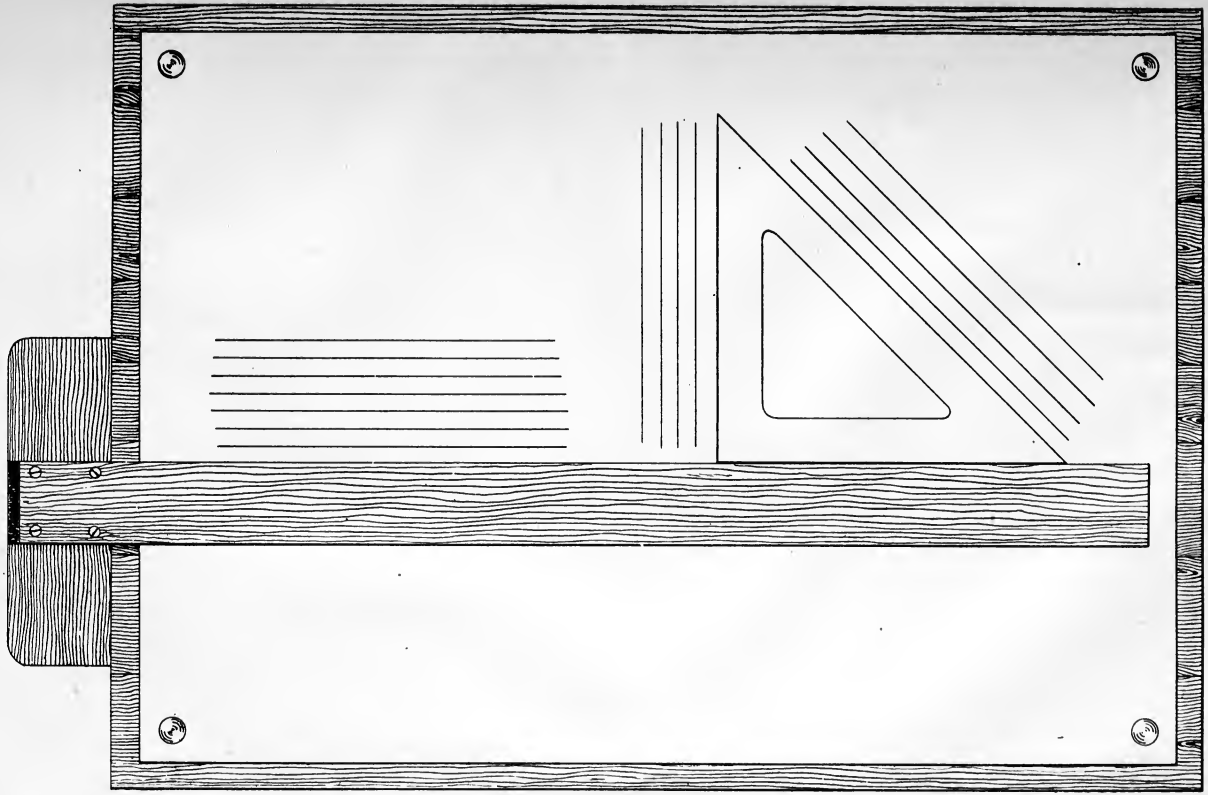


Fig. 4. Drawing Board with T-square and Triangle in place showing Method of Drawing Horizontal, Vertical and Inclined Lines.

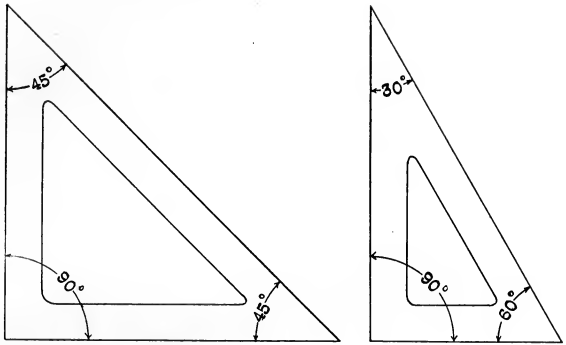


Fig. 5. 45 and 60 Degree Triangle.

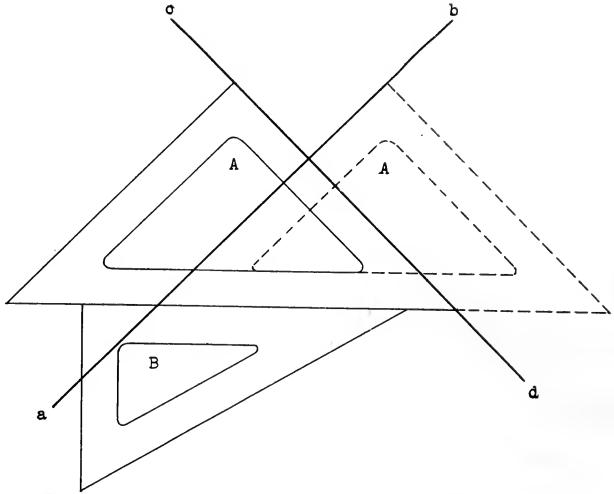


Fig. 6. Method of Drawing Perpendicular Lines.

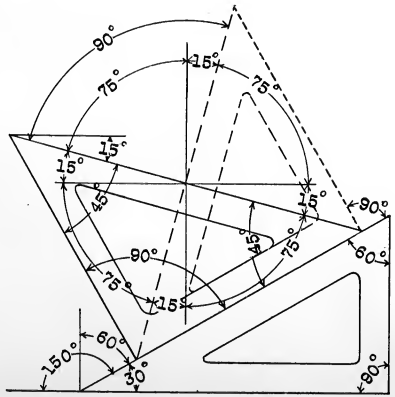


Fig. 7. Positions of Triangles to obtain Various Angles.

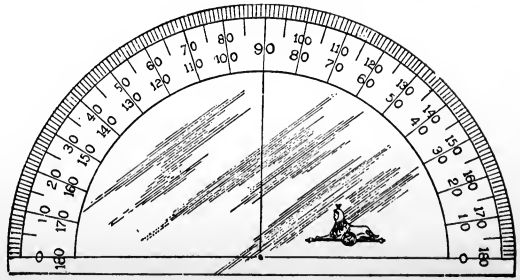


Fig. 8. Protractor.

5. T-SQUARE. The T-square (Fig. 4) consists of a long, light blade attached at right angles to a head which slides along the left side of the drawing board. All horizontal lines are drawn by moving the pencil along the top edge of the T-square, whose head is held snug against the left edge of the board. Do not hold the head against the bottom edge of board to draw vertical lines.

6. TRIANGLES. The best triangles are made of transparent celluloid, not less than $\frac{1}{16}$ in. thick. Triangles of 45 and 60 degrees are generally used. (See Fig. 5).

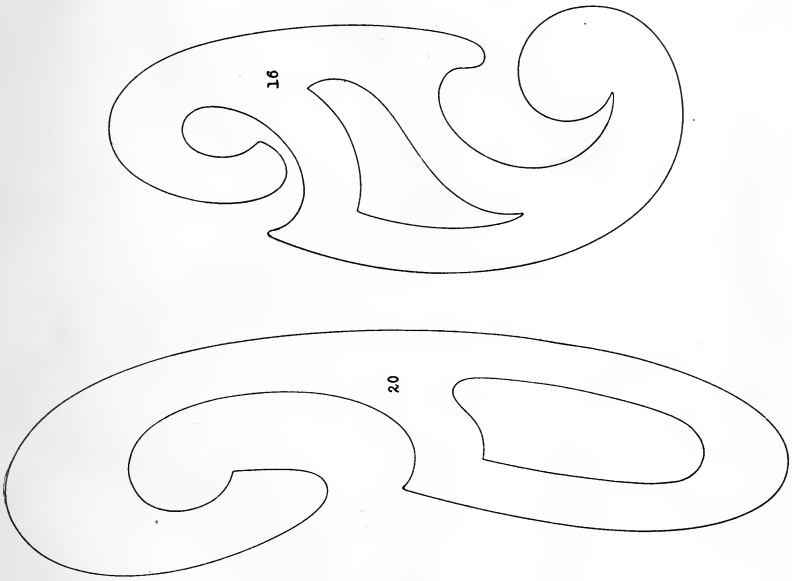


Fig. 9. Irregular Curves.

All vertical or slanting lines are drawn with the aid of triangle (Fig. 4).

To draw a line perpendicular to a slanting line. In Fig. 6 place the short edge of triangle *A* along line *a b*, perpendicular to which a line is to be drawn. Holding triangle *A* in place lay triangle *B* against it; slide triangle *A* to position *A'* and draw line *c d*, which will be perpendicular to line *a b*.

The positions of triangles to obtain lines at various angles are shown in Fig. 7. To obtain other angles a protractor is used. (Fig. 8).

7. IRREGULAR CURVES OR SWEEPS. These are used for drawing smooth curves which are not parts of a circle, using either pencil or ruling pen. The two types of curves most useful are shown in Fig. 9.

The proper method of using such curves is as follows: Suppose, in Fig. 10, it is desired to connect points *a, b, c, d, e,* and *f* by a smooth curve. Lay the irregular curve in position *A* so that one of its sweeps touches 3 points, say *a, b* and *c,* and draw the curve as

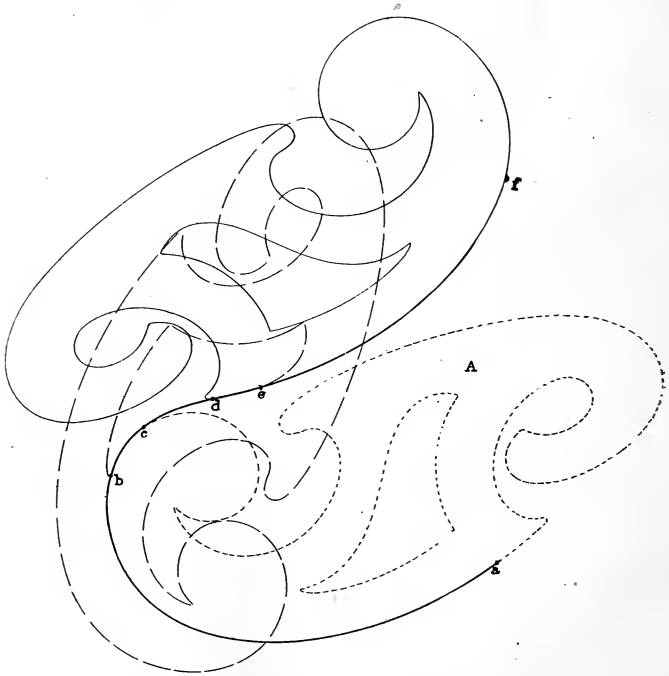
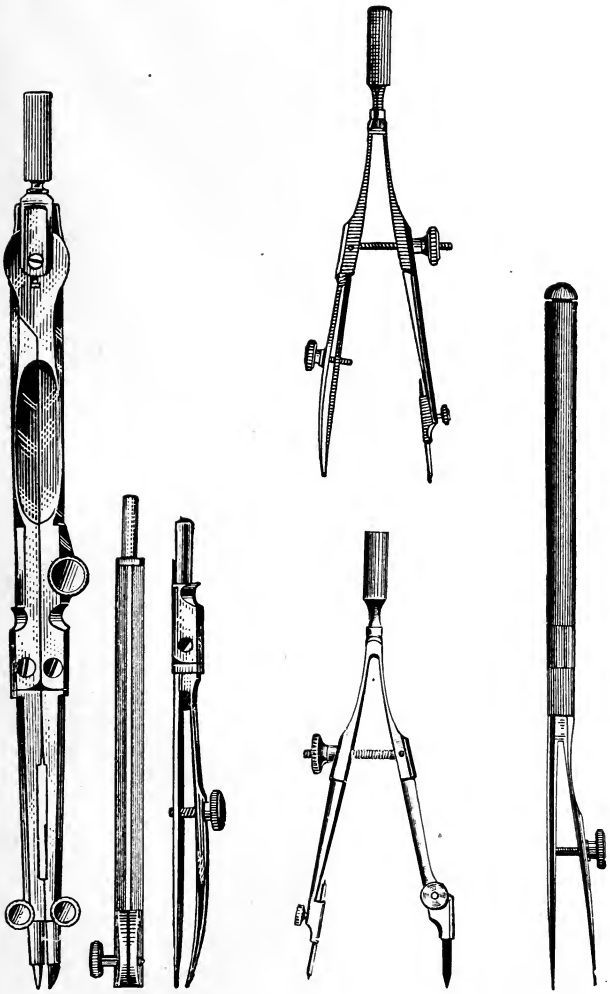


Fig. 10. Method of Using Irregular Curves.

far as *c*. Now start with *b* and cover *b, c* and *d*. Repeat until the curve is completed, always, however, starting back one point so as to obtain a smooth curve.

8. COMPASS. The compass (Fig. 11) is used to draw arcs and circles, either in pencil or ink. Each leg is provided with a joint so that the lower portion can be kept perpendicular and both nibs of the pen bear equally on the paper. The pin point should have a square shoulder so that it cannot make a large hole in the paper.



11 12 13

Fig. 11. Compass with Pen and Pencil Attachments and Lengthening Bar.
Fig. 12. Bow-pencil and Bow-pen.
Fig. 13. Ruling Pen.

Fig. 14. Method of Using Ruling Pen.

Always use a hard lead in the pencil attachment.

When it is desired to draw large circles, the lengthening bar is inserted between the upper part of leg and the pencil or pen attachment.

The compass should be gauged with one hand, the thumb and fourth finger holding the needle point leg, which is generally set on the drawing first, and the pencil or pen point between the first and second fingers, which move the point to the desired setting.

When drawing circles the compass should be held at the top between the thumb and first finger, bringing slight pressure to bear on the pencil or pen point, but none on the pin point. The compass should lean slightly in the direction in which it rotates.

9. DIVIDERS. The dividers are simply a compass fitted with two long needle points and are used for transferring dimensions or spacing off. The compass shown in Fig. 11 can be converted into dividers by reversing the shoulder needle point and replacing the lead in the pencil attachment with the extra needle point provided. In using the dividers prick the paper only slightly; the smaller the mark the better.

10. BOW PENCIL AND BOW PEN. (Fig. 12). These are used for drawing small arcs and circles, as they are much easier to handle and give better results. The needle point should be adjusted to the same length as the pencil or pen point.

11. RULING PEN. The ruling pen (Fig. 13) is used to ink in all straight lines and irregular curved lines. The pen should be held lightly in the right hand (Fig. 14) in a vertical position, so that both nibs touch the paper and inclined in the direction in which the pen moves. The third and fourth fingers should rest on and slide along the T-square or triangle. The pen should be held lightly and not pressed against the side of the T-square or triangle, the thumb screw being kept on the far side of the guiding edge.

Ink is filled in the space between the nibs, not more than ¼ in. along the blades, by means of the quill attached to the cork of the drawing ink bottle. Great care should be taken to keep the blades clean, and no ink should be on the outside, as blots will surely result. If the ink does not run freely, clean the pen by releasing the cleaning device under the thumb screw and wiping the nibs with a soft rag.

To adjust the ruling or compass pen for thickness of line, the thumb screw is rotated by the thumb and middle finger. Do not

try to draw so fine a line that the nibs of the pen touch each other, as the ink then can not flow freely.

The pens cannot be cleaned too often.

12. ERASERS. For pencil line use the emerald eraser. For ink lines use the same eraser, and under no conditions use a knife, as this is bound to spoil the paper. For a general cleaning of the drawing without removing lines, use artgum or a soft cleaning rubber.

II. Standards for Drawings

1. Sizes. Every drawing room has standard sizes for the drawings so they can be filed and each easily located. In this course the sizes will be 14 x 20 in. and 20 x 28 in., with a ¾ in. margin. The layout of a 14 x 20 in. sheet is given in Lesson 1—Course A.

2. Titles. Unless otherwise indicated, all drawings in this course shall have titles as shown in Lesson 1—Course A, neatly lettered on the margin and reading from the outside, as shown.

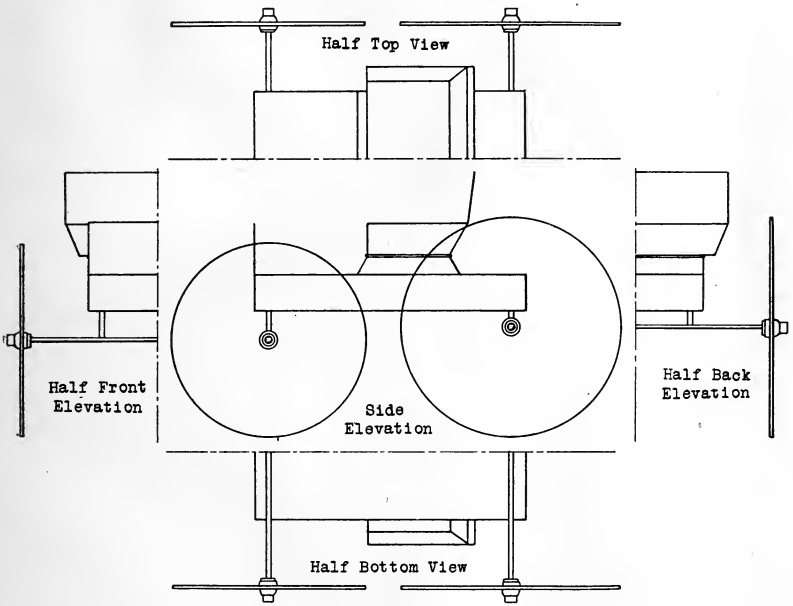


Fig. 15. Arrangement of Views.

3. Arrangement of Views. The different views of an object should be located as per Fig. 15.

4. Lines. Each of the different kinds of lines (Fig. 16) used in a drawing has a definite meaning and use. All lines showing any part of the object, whether full, dotted or irregular lines, are of the same weight or thickness, except shade lines, which are three times as heavy; all other lines are lighter.

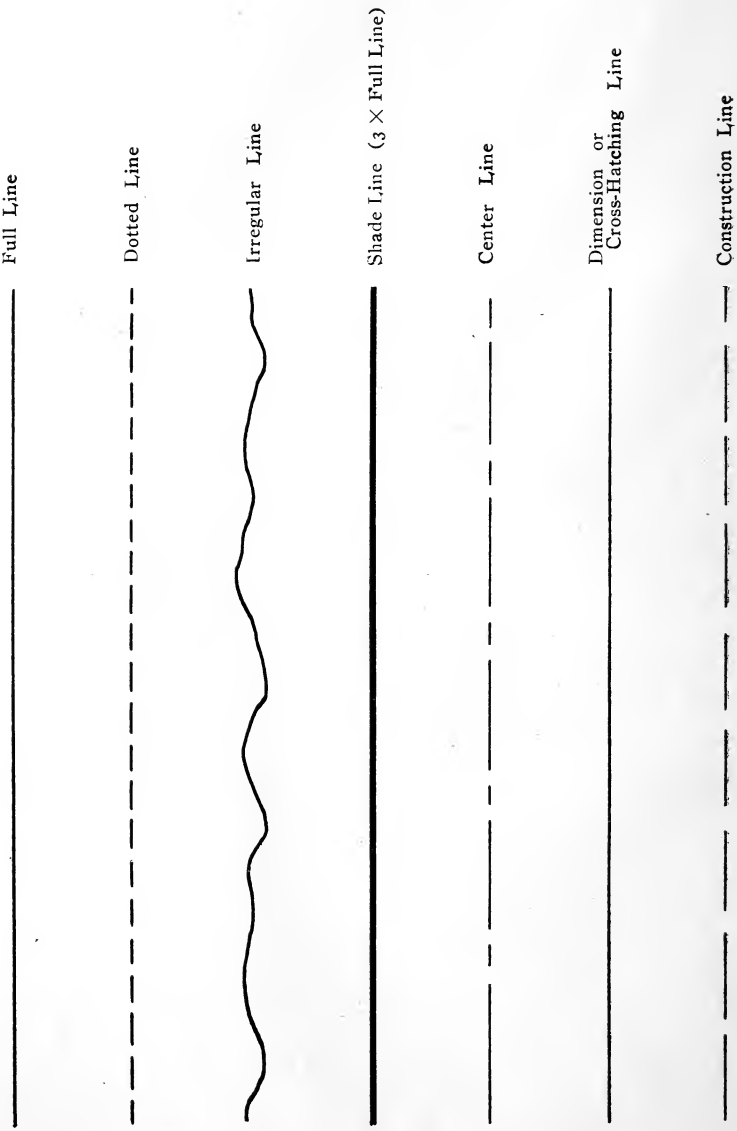


Fig. 16. Sample Lines Showing Exact Weight to be Used on Drawings.

a. *Full lines* are used to show all unobstructed edges of the object.

b. *Dotted lines* are used to show all hidden edges of the object. The first and last dot of a dotted line should touch the lines at which the hidden edge actually terminates.

c. *Irregular lines* represent the edge of a surface where a part is broken away to show the interior.

d. *Center lines* give the axis of symmetry, centers of circles, etc.

e. *Dimension lines* are used to show the size of the various parts of an object. The arrowhead should be made with the stroke of the pen towards the point, which should just touch the line from where the dimension reads.

f. *Construction lines* are used to show the method employed to obtain the result shown in the drawing. These should touch the points between which they are drawn.

5. INKING IN. A drawing should not be inked in until it is complete in pencil. The ink lines should be of the thickness shown in Fig. 16.

In order to secure the best results and save time, the inking should be done in the following order:

a. Ink all full or dotted line circles and circular arcs, beginning with the smallest.

b. Ink all other curved lines, full or dotted.

c. Ink all horizontal full and dotted lines, working downward from the top.

d. Ink all vertical and inclined full and dotted lines, working from left to right.

e. Ink all construction line circles and circular arcs.

f. Ink all horizontal construction lines, working down from the top.

g. Ink all vertical and inclined construction lines, from left to right.

h. Ink all center and dimension lines.

i. Ink cross hatching.

j. Ink border lines, which should be heavier than the full lines.

k. Ink dimension figures, notes and titles.

III. Lettering

To make a drawing entirely clear it is always necessary to place on the same dimensions, explanatory notes, titles, etc. This should be done with a plain, legible style of letter, easily executed. The appearance of a drawing, well made as far as the lines are concerned, is often spoiled by poor lettering. The beginner will generally experience difficulty in executing neat lettering, but a little practice will produce wonderful results.

1. Style. The style of lettering which seems to best meet practical conditions is that developed by Mr. C. W. Reinhardt and given in Figs. 17 and 18. Slanting lettering is mostly used, although the same style can be executed vertical, which is done for all titles of large letters. Letters consist of capital letters (called upper case) and small letters (called lower case).

2. Size. In general, the lower case or small letters are three-fifths the height of capital letters. The usual height is 5/32 inch for capitals, making the lower case letters 3/32 inch, as shown in Fig. 17. Always draw parallel lines as a guide for top and bottom of letters as shown. This is necessary for beginners, and is done by experienced draftsmen.

3. Slant. The slant or inclination of letters is usually 1 to 2½, about 70 degrees, as shown. An angle of 60 degrees is satisfactory, which enables one to draw the slanting guide lines by means of a 60-degree triangle held against the T-square. Such guide lines are necessary for a beginner and may be dispensed with only after sufficient practice enables one to give to all lettering a uniform inclination which is essential to a good appearance.

4. Execution. All lettering on drawings should first be penciled and then inked in. All practice lettering should be done with drawing ink.

a. Pen Point. A Falcon pen point is recommended, which should be limbered up so as not to be too stiff. This is done by holding the nibs of the pen with a cloth and working the end of pen back and forth. One can then produce heavy lines without pressing on the pen unduly.

b. Thickness of Lines. All the lines forming a letter should be of a uniform thickness. There should be no fine lines in any letter. They should all be as heavy as shown.

c. Letters. The small and capital letters should be made exactly the same shape as shown. Following the lines showing the small letters, also the capitals, the same are repeated with the separate strokes of the pen shown, an arrow indicating the direction in which the pen moves in forming that part of the letter. It should be carefully noted which part of the letter follows the general slant.

d. Figures. The construction of the figures is shown the same as of the letters. In the case of fractions, a horizontal line, half way between top and bottom of regular figures, is drawn as the fractional dividing line and the figures of the fraction, ⅗ the size of the regular figures, are so made that a slant guide line through the center of the numerator will pass through the center of the denominator.

5. SPACING OF LETTERS AND WORDS. The blank spaces between letters of the same word should always be the same, say about ⅓ the height of body of letter. For small letters this would be about 1/32 inch, for capitals about 2/32 inch.

The spaces between words should all be equal and about the length of the letter l or 5/32 inch.

6. PRACTICE PLATES. The following practice plates should be carefully and neatly lettered, and on the completion of each individual letter the same carefully compared with the sample letters shown, so as to correct any discrepancies in the next letter. It is essential that the pen be moved very slowly in forming a letter, the hand constantly guiding the point to produce the proper shape. Especial care should be taken to extend letters fully to top and bottom guide lines; the letters should not fall short or extend beyond.

In the following plates one line of each letter given should be made and this repeated until the sheet of paper is filled:

Plate	I.	i, l, j, t, f
	II.	h, m, n, u, y, v, w
	III.	k, r, x, z, s, e
	IV.	o, p, b, c, a, d, g, q
	V.	I, L, F, E, H
	VI.	A, V, W, K, X, Z
	VII.	T, N, M, Y, J
	VIII.	P, R, D, B, U
	IX.	C, G, O, Q, S
	X.	1, 7, 4, 3, 2, 5, 0, 6, 9, 8.

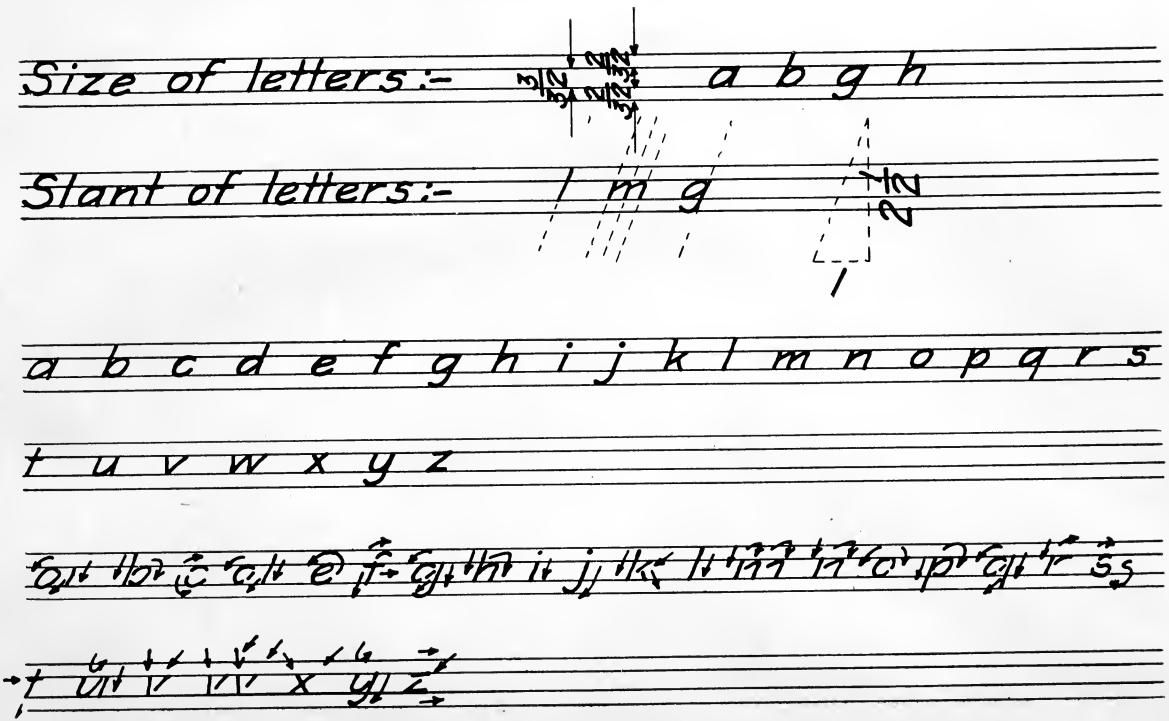


Fig. 17. Lettering.

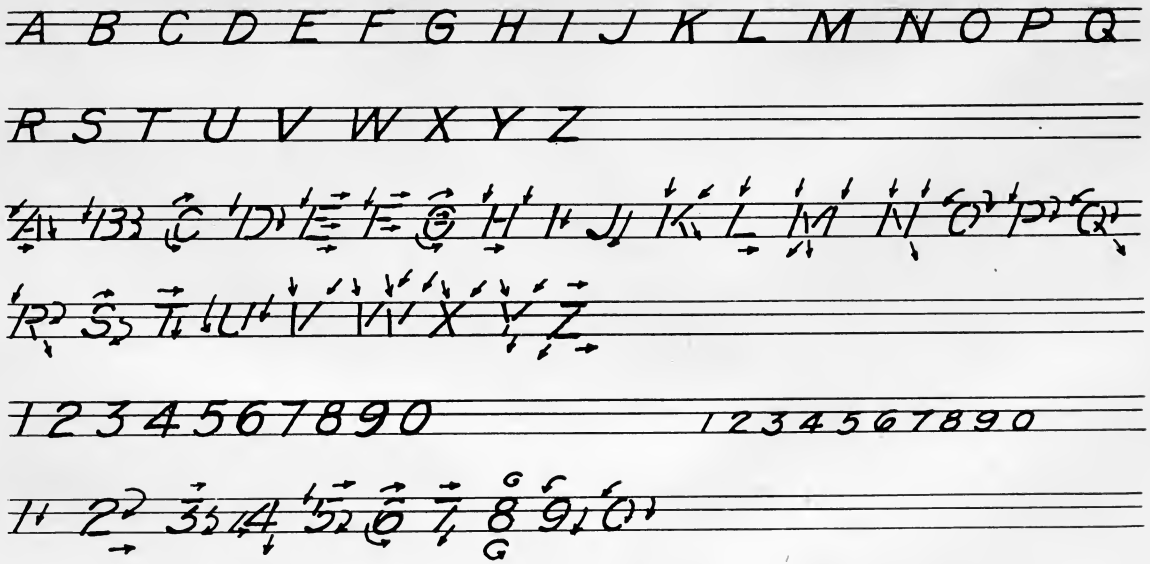


Fig. 18. Lettering.

IV. Sections and Cross-Hatching

1. Sections. In order to make the construction of an object more clear, it is often desirable to show the interior. This is accomplished by means of a section, i. e. the near portion of the object is considered to be cut away and the lines drawn to show the interior, Fig. 19.

If a section is shown along a center line this should be indicated by a note on the drawing "Section on A-B." If the section is not

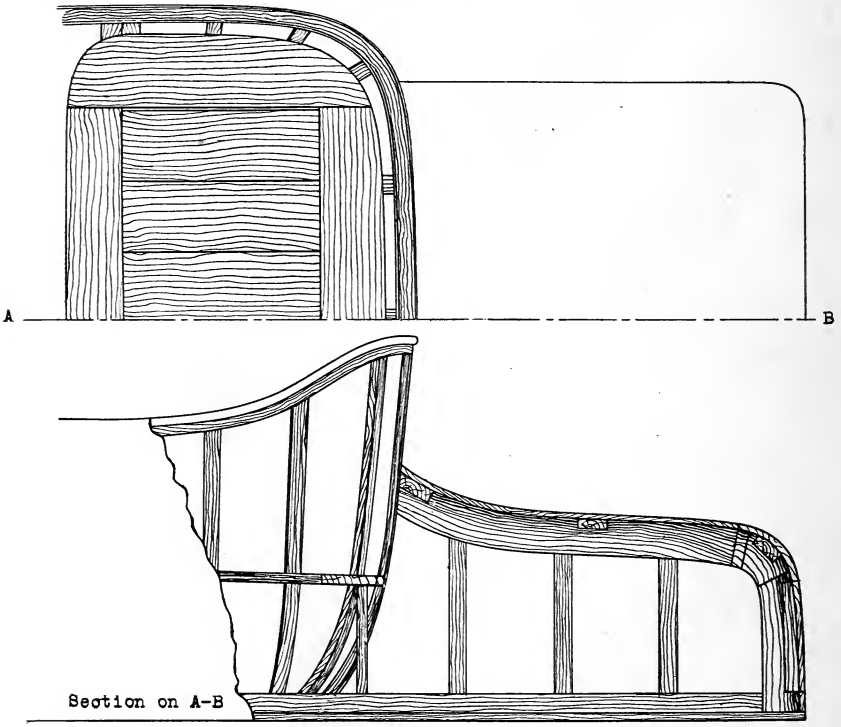


Fig. 19. Drawing showing Sections and Cross-hatching.

along a center line the edge of the near portion cut away, is indicated by an irregular line.

2. Cross-Hatching. In a section it is often necessary to cut through a portion of material, the character of which is indicated by the spacing and thickness of lines as per Fig. 20. The slant is 45 degrees, unless otherwise indicated.

When two separate pieces, either of the same or different materials, adjoin each other, the cross-hatching lines are drawn in opposite directions.

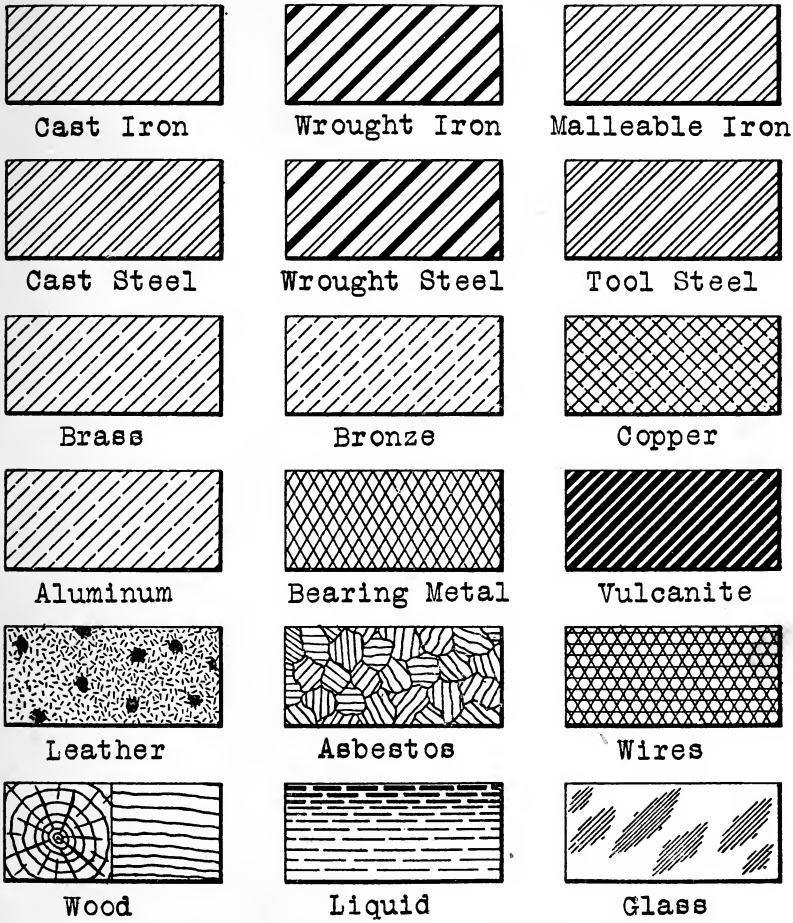


Fig. 20. Conventional Cross-hatchings.

The spacing of the lines is done by the eye and uniformity is necessary to good results. It is often a great help to glance at the two or three previous spaces when setting the next one.

3. BREAKS. When a long piece cannot be shown full length and it is desired to show both ends, a break is made at a convenient place, as shown in Fig. 21.

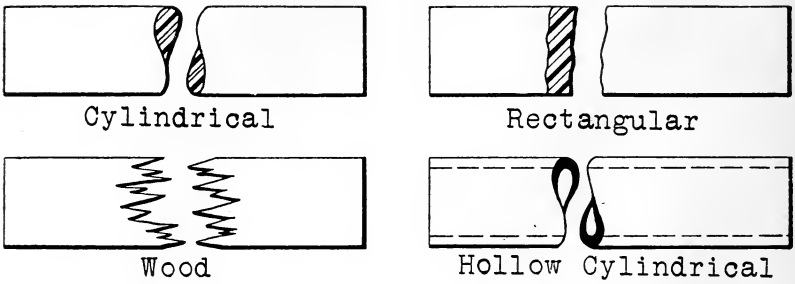


Fig. 21. Method of showing Breaks in Long Pieces.

V. Scales

1. Systems of Measurement. There are two systems of measurement of length used in drawings. These are the *English or American,* where the unit of length is 1 foot, which is divided into twelve inches, and the *French or Metric,* where the unit of length is 1 meter, which is divided into 100 centimeters or 1,000 millimeters.

2. Scales of Drawings. It is not practical generally to lay out an object to actual dimensions on a sheet of paper of convenient size. Therefore, the object is drawn smaller, say ½, ¼ or 1-16 of the actual size. In order to save time, use is made of a scale, such as shown in Fig. 22, where the lengths are shown to the reduced size. The triangular scale shown has six faces and different scales are marked on each of them.

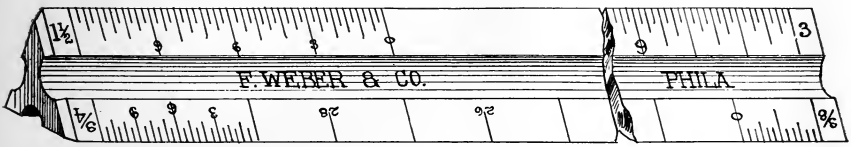


Fig. 22. Triangular Boxwood Scale.

Drawings of vehicle bodies are sometimes made full size, but mostly to a reduced scale.

In the *American System,* Fig. 23, for a scale of ½ inch to the foot, each 1 foot of actual length of the object is represented in the drawing by a length of ½ inch, which is one division of the scale. Each division is divided into twelve parts, each part representing 1 inch of actual length of the object. If the scale is 1 inch to the foot, then each 1 foot of length of the object is 1 inch long in the drawing, etc.

In the *Metric System,* Fig. 24, for a scale of 5 centimeters to the meter, each 1 meter of actual length of the object is represented in the drawing by a length of 5 centimeters, which is one division of the scale. Here, however, each division is divided into ten parts, each part representing 1-10 of 1 meter or 10 centimeters of actual length of the object.

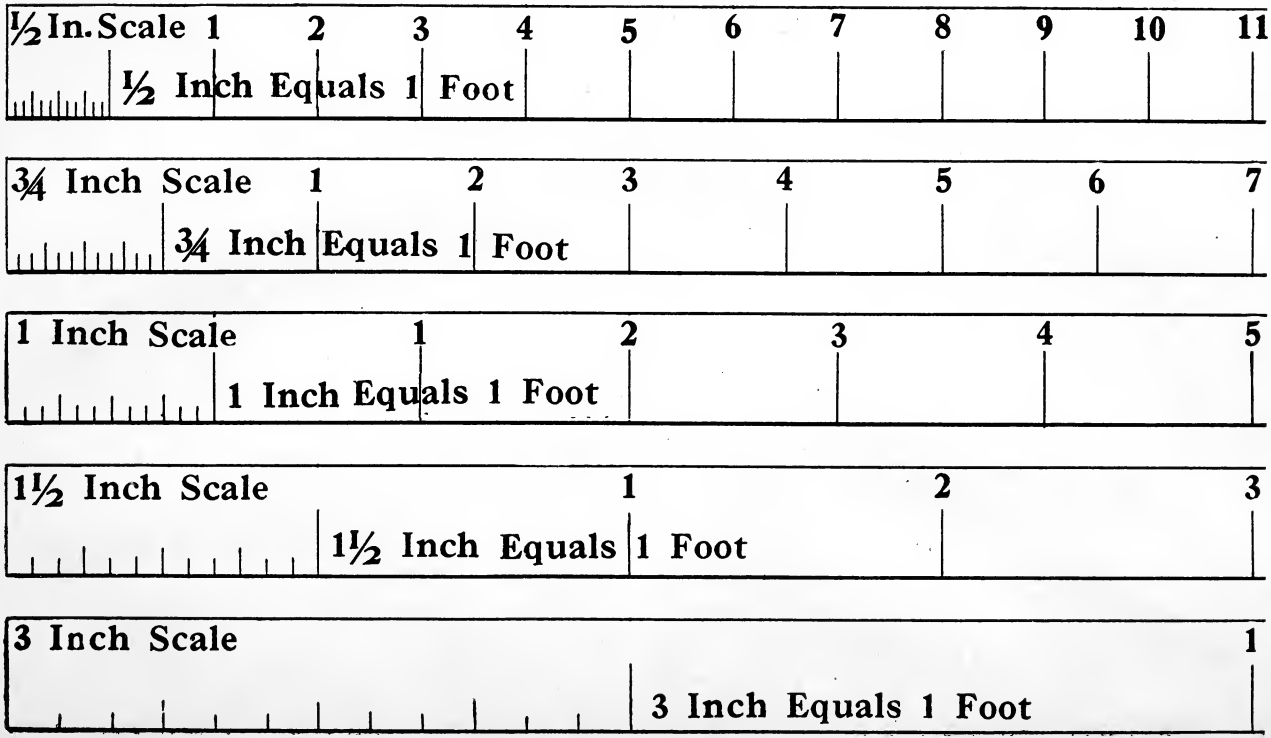


Fig. 23. Scales on American System.

FIG. 24. Scales on Metric System.

3. SCALES IN GENERAL USE. The scales generally used are:

American System—½, ¾, 1, 1¼, 2 and 3 inches to the foot.

Metric System.—2½, 3, 5 or 10 centimeters to the meter. Small "Fashion Plates" are drawn to a 2½, or 3-centimeter scale, and large "Fashion Plates" to a 5-centimeter scale. A 10-centimeter scale is mostly used for working drafts, and this represents a reduction of 1 to 10.

4. USE OF SCALES. It will be noted that at the end of each face of scale, Fig. 22, 1 ft. is divided into inches and fractions, and on the other side of the zero mark only feet divisions are indicated. To lay off a dimension of feet and inches, for example 2 ft. 3 in., measure from the 2 ft. mark back to 0 and then to the 3 in. mark.

In laying off dimensions the scale is laid directly on the drawing and the desired length marked off with a sharp pencil. The divider or compass should not be held against the scale and the lengths then marked on the drawing, as this will not give accurate results and at the same time destroys the markings on the scale.

VI. Shading

1. Shade Lines. It is often desirable to make more clear the shape of an object by indicating the raised or depressed surfaces by means of shade lines and thus overcoming the flatness of a drawing. Shade lines are three times the thickness of full lines, see Fig. 16.

It is considered that the light emanates from the upper left-hand corner of a drawing in parallel rays at an angle of 45 degrees, see Fig. 25. The shade line is used to separate a surface receiving the light from one which does not. It is not considered that one portion of an object casts shadows on another portion. By sliding a 45 degree triangle along the T-square and assuming the hypotenuse to be a ray of light, the surfaces upon which the light rays do not impinge can be easily determined, and these then shaded.

To shade a circle or arc draw a line at 45 degrees through the center and move the needle point, without changing the radius or the setting of pen, downward along this line a distance equal to the maximum thickness of shade line. The space between can be filled in by slightly springing the pen point.

2. Line Shading. In order to more clearly illustrate the nature and relative positions of the surfaces of an object, line shading is resorted to. This is accomplished by drawing parallel or converging lines which decrease in thickness and increase in spacing from the darker to the lighter portion of a surface. The rays of light are considered to be at 45 degrees.

The method of line shading various surfaces is illustrated in the following surfaces:

Fig. 26. Cylinder and interior of curved surface.

Fig. 27. Prism.

Fig. 28. Cone.

Fig. 29. Sphere.

Fig. 30. Pyramid.

Fig. 31. Combination of curved surfaces.

3. Tint Shading. Shading by means of hand or air brush gives a much better effect and is used when a high class drawing is desired. Figs. 32-36 illustrate such work.

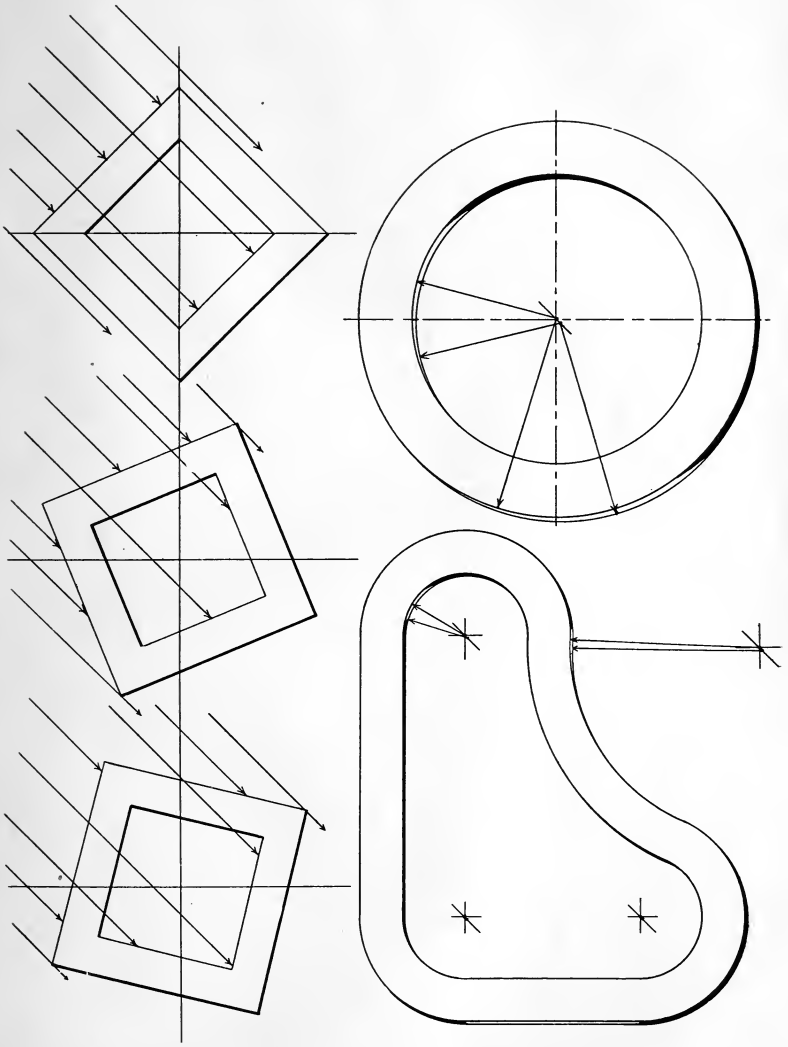


Fig. 25. Shade Lines.

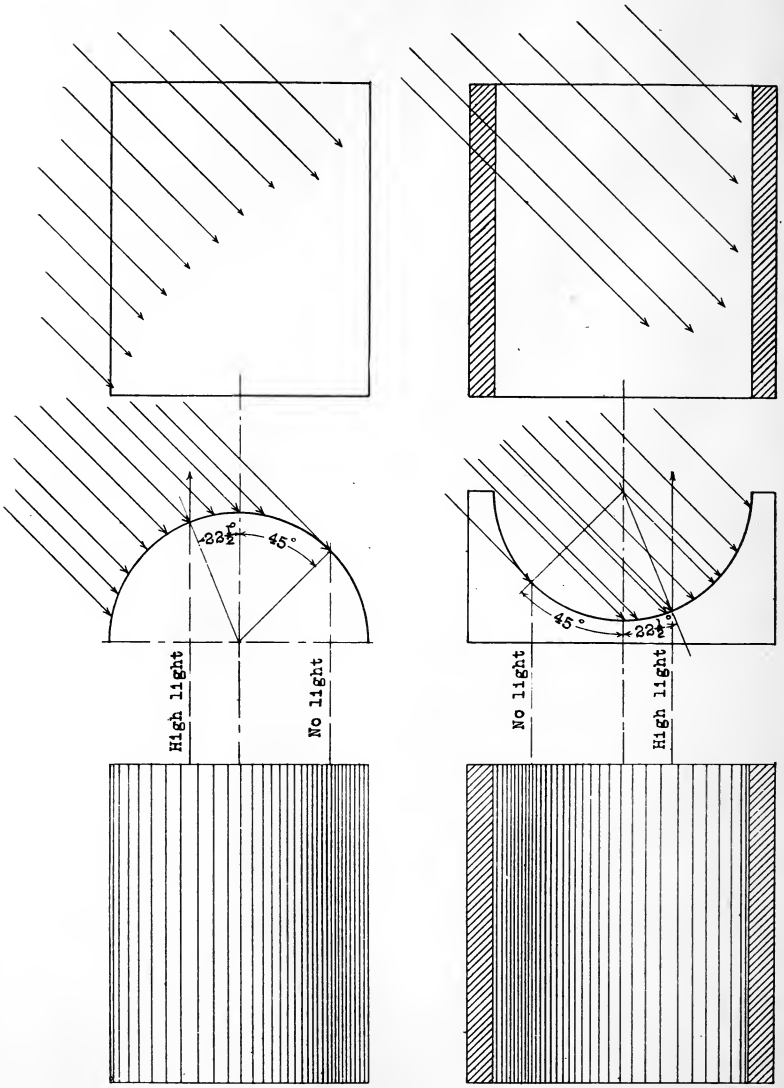
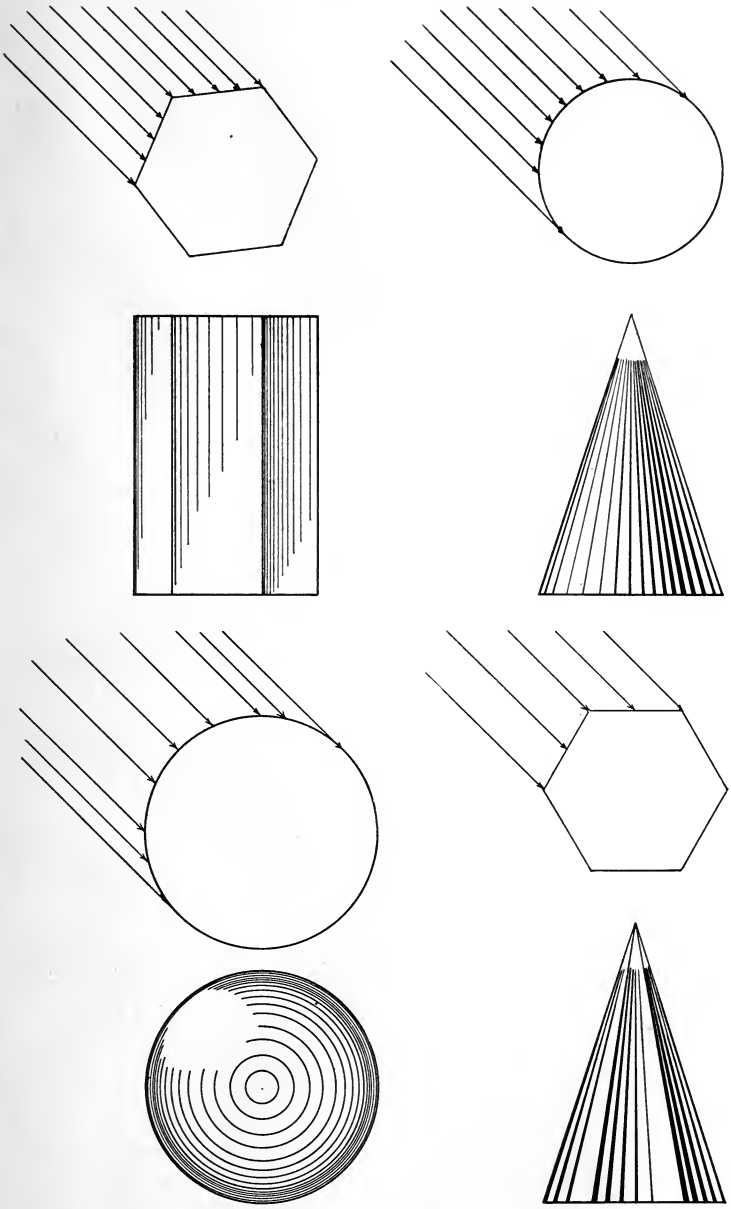


Fig. 26. Method of Line Shading.



Figs. 27-30. Line Shading of Solid Bodies.

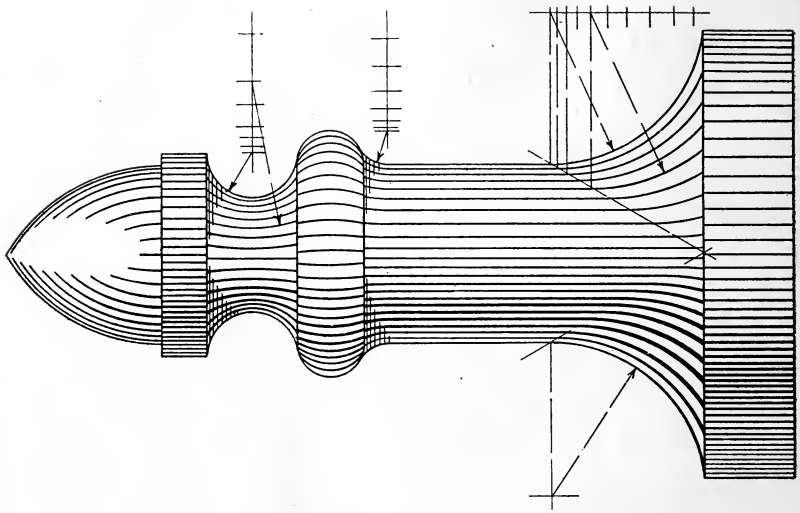


Fig. 31. Method of Line Shading Combination of Curved Surfaces.

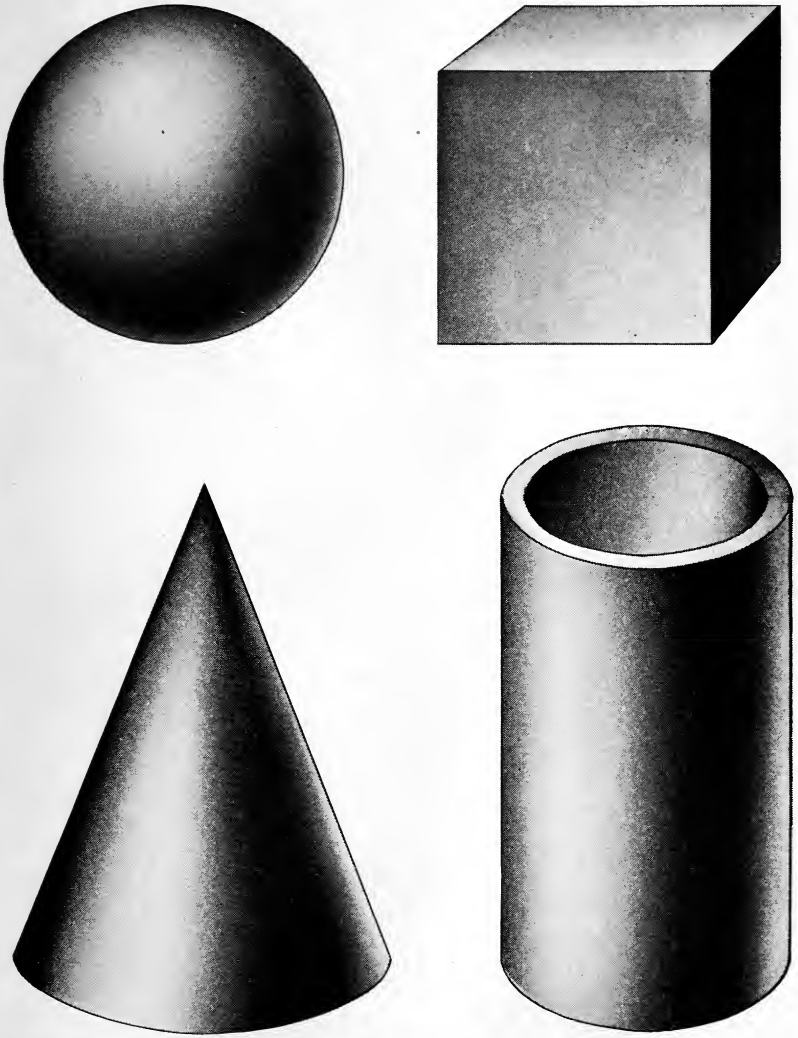


Fig. 32. Tint-shading.

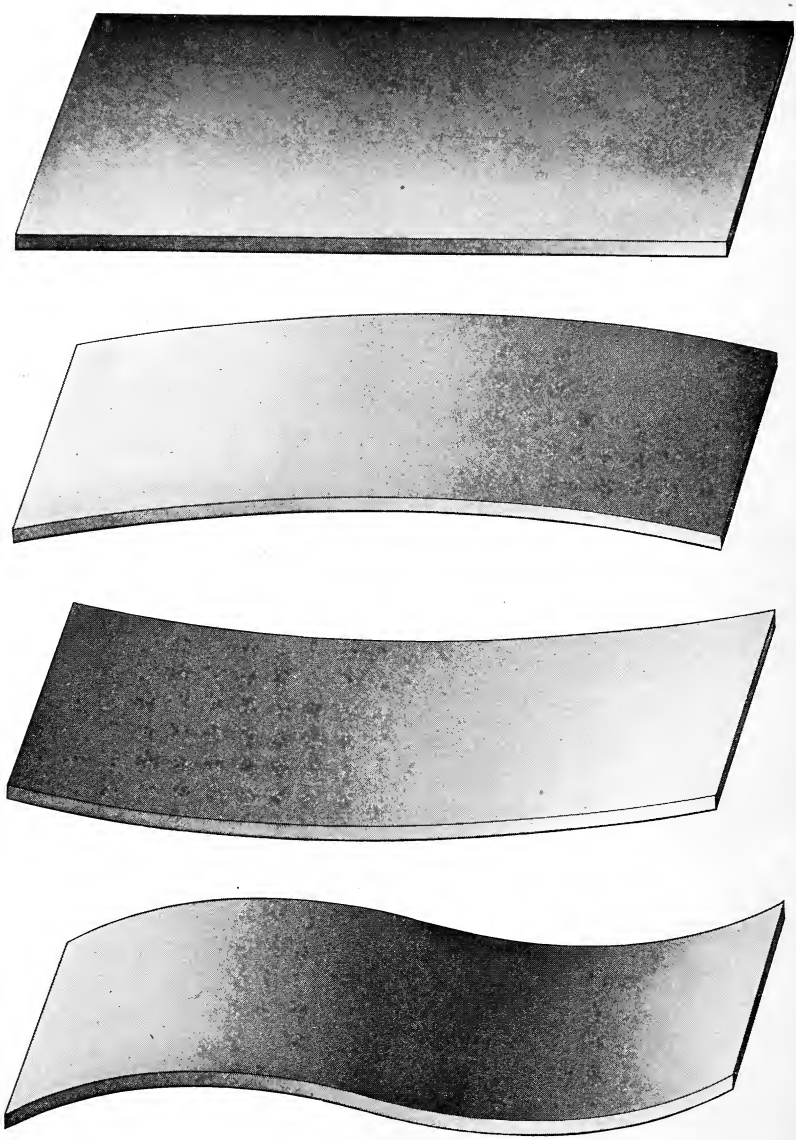


Fig. 33.

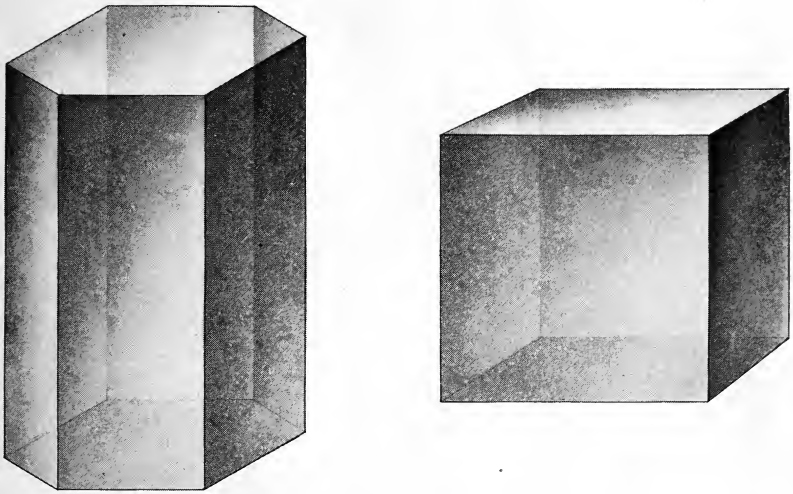


Fig. 34.

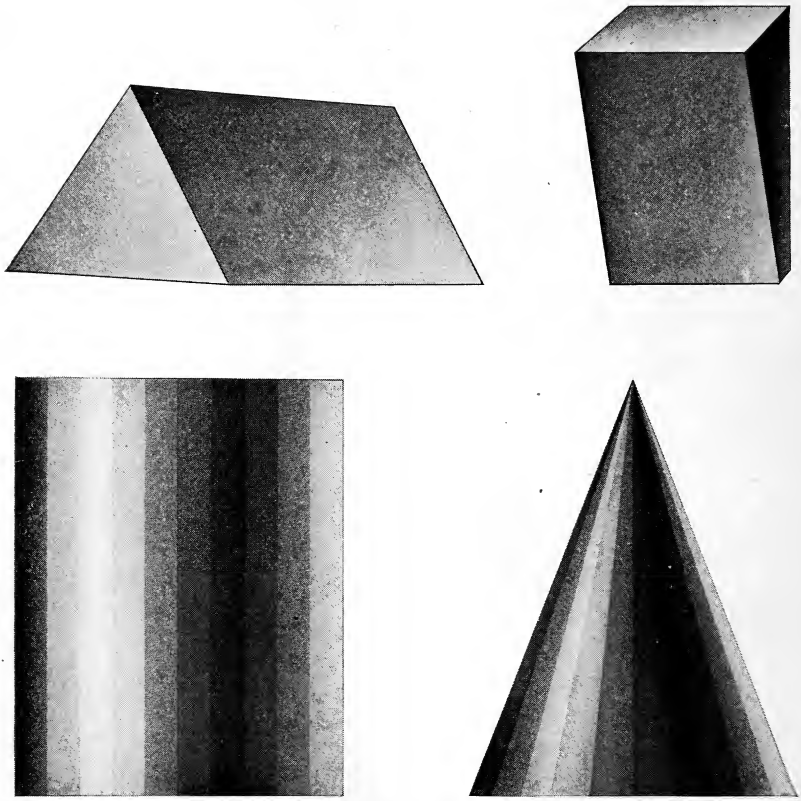


Fig. 35.

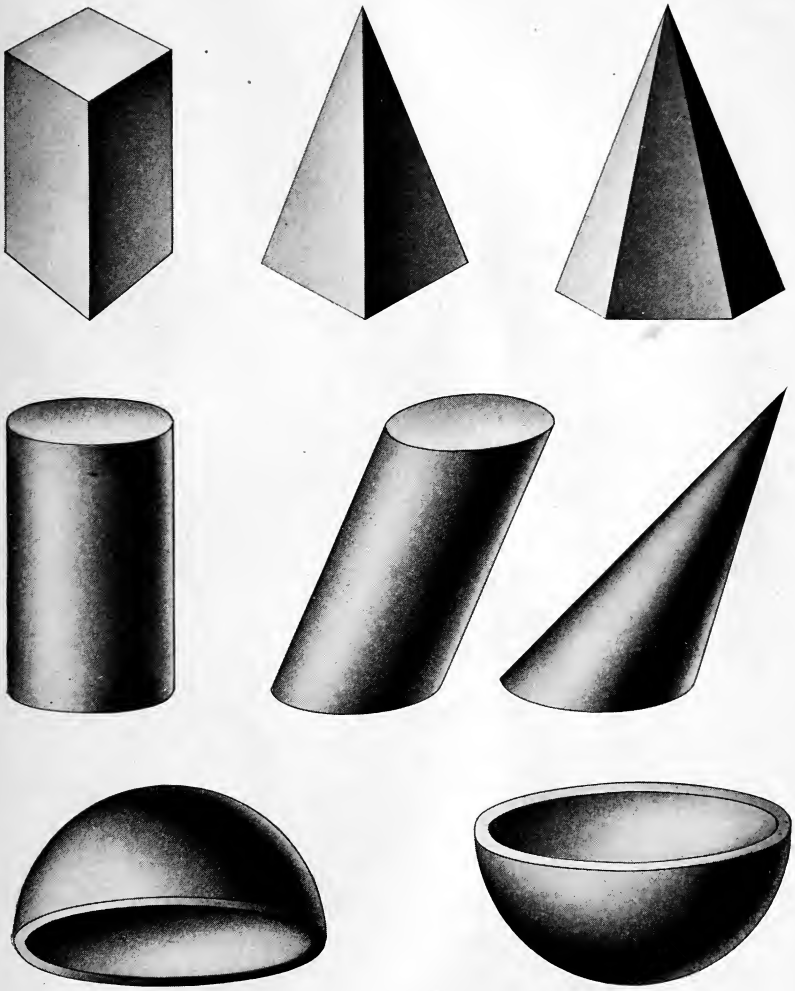
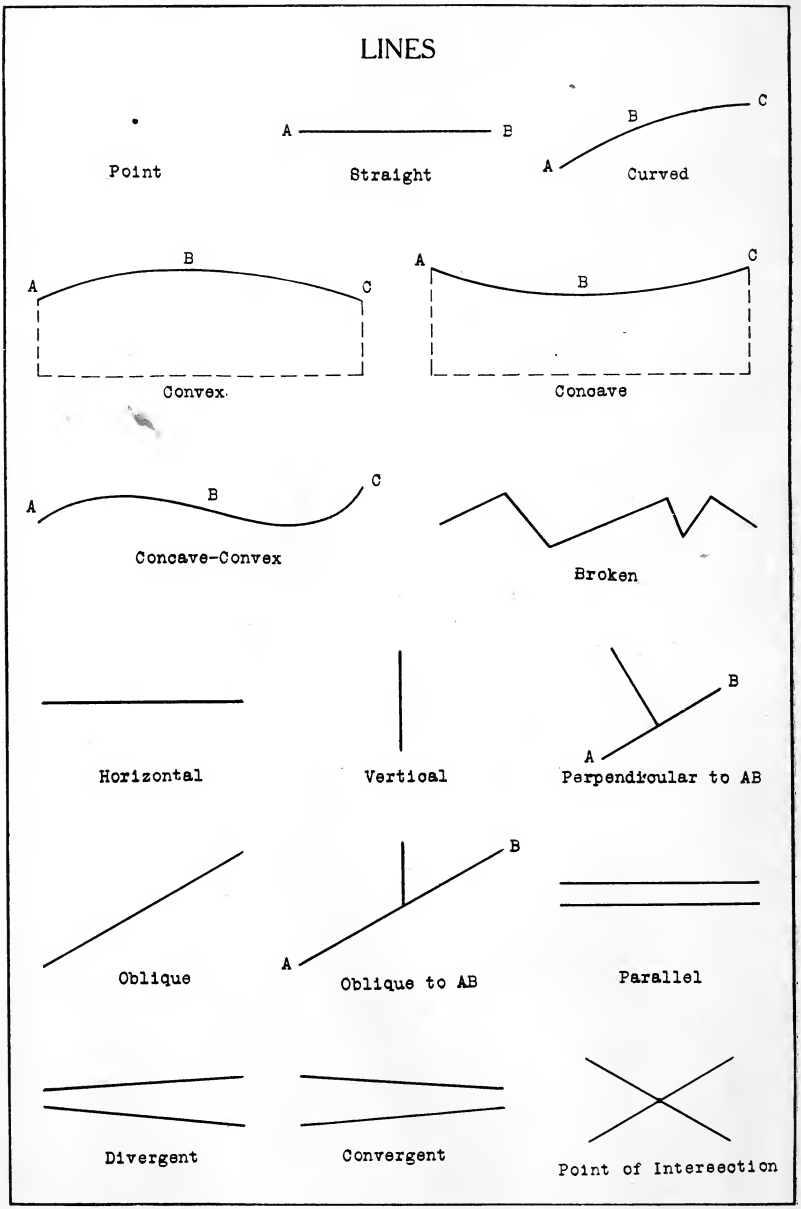


Fig. 36.


LINES
Point
A
B
Straight
A
B
C
Curved
A
B
C
Convex
A
B
C
Concave
A
B
C
Concave-Convex
Broken
Horizontal
Vertical
A
B
Perpendicular to AB
Oblique
A
B
Oblique to AB
Parallel
Divergent
Convergent
Point of Intersection

GEOMETRICAL DEFINITIONS

Geometry is that branch of mathematics which treats of the properties of lines, angles, surfaces and solids.

I. The Point

1. A *point* indicates position only. It has neither length, breadth nor thickness.

II. The Line

1. A *line* has only one dimension, that is length. A line is considered to be the path of a moving point.

2. A *straight line* is one which does not change its direction in any part of its length. It is the shortest distance between two points.

3. A *curved line* changes its direction at every point.

   a. A *concave* curved line is one which curves inwardly.

   b. A *convex* curved line is one which curves outwardly.

   c. A *concave-convex* or *reverse curve line* is one which has both a concave and a convex curve.

3. A *broken line* consists of several joining straight lines of different directions.

4. A *horizontal line* is one which is level with the horizon or with the surface of water at rest. A line parallel with the top of a drawing is generally called a horizontal line.

5. A *vertical line* has the direction of a plumb bob line. It is at right angles to a horizontal line.

6. A *perpendicular line* is a line vertical to a horizontal line. A line is perpendicular to another line when it does not incline on either side towards it.

7. An *oblique line* is one which is neither horizontal nor vertical. A line is oblique to another line when it is not perpendicular to the line considered.

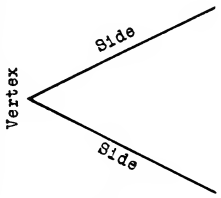
8. *Parallel lines* are equi-distant from each other at every point.

9. *Divergent* lines continually recede from each other, such as lines radiating from one point.

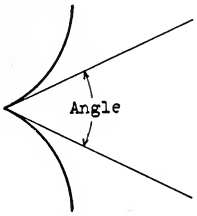
10. *Convergent* lines are continually coming closer to each other. These are also called *contracting* lines.

11. The *point of intersection* is where two or more lines cross each other.

ANGLES

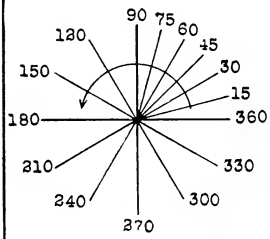


Straight Line

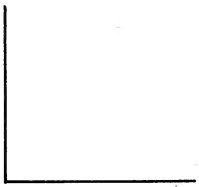


Curved Line

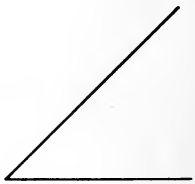
Spherical.



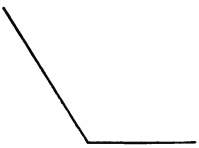
Degrees



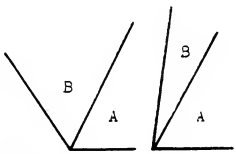
Right



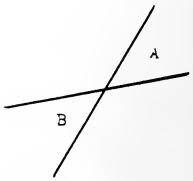
Acute



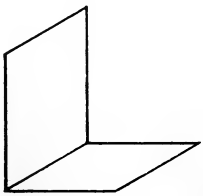
Obtuse



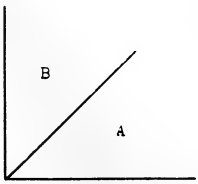
Adjacent



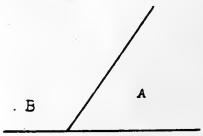
Opposite



Dihedral



Complementary



Supplementary

III. The Angle

1. An *angle* is formed by two intersecting lines called the sides, and is measured in degrees. The point of intersection is called the vertex.

2. A *straight line angle* is one in which the intersecting lines are straight lines.

3. A *curved line angle* is one in which the intersecting lines are curves. The angle is measured by lines tangent to the curves at the vertex.

4. A *spherical angle* is one in which the intersecting lines are arcs of the same radius.

5. A *degree* is the 1/360 part of the circumference of a circle. Each degree is divided into 60 minutes, and each minute into 60 seconds.

6. A *right angle* is one in which the intersecting lines are perpendicular to each other. A right angle has 90 degrees, or one-quarter of a circle.

7. An *acute angle* is smaller than a right angle and, therefore, has less than 90 degrees.

8. An *obtuse angle* is greater than a right angle and has, therefore, more than 90 degrees.

9. An *oblique angle* is one which is not a right angle.

10. *Adjacent angles* are angles which have one side and the vertex in common.

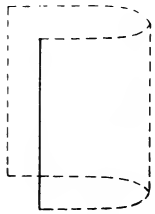
11. *Opposite* or *vertical angles* are formed by two intersecting straight lines which form the two sides of the angles and the point of intersection is the common vertex. They always have the same number of degrees.

12. A *dihedral angle* is one formed by the intersection of two surfaces at various degrees.

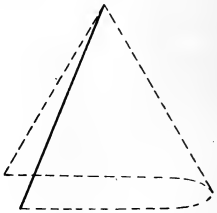
13. *Complementary angles* are such that together they form a right angle, *i. e.,* add up to 90 degrees.

14. *Supplementary angles* are such that together they form two right angles, *i. e.,* add up to 180 degrees.

CURVED SURFACES

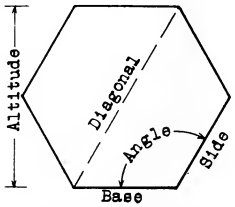


Cylindrical Surface



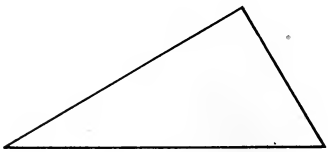
Conical Surface

PLANE FIGURES

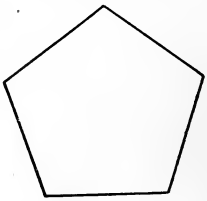


Regular Polygon

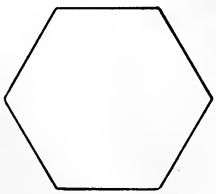
Irregular Polygon



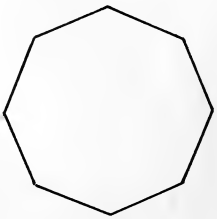
Triangle



Pentagon



Hexagon



Octagon

IV. Surfaces

1. A *surface* has only two dimensions, length and breadth.

2. A *plane surface* is one that is perfectly flat. If a straight edge be laid on it in any position the same will touch the surface at every point.

3. A *curved surface* is one that is not a plane surface.

   a. A *cylindrical surface* is a curved surface generated by a straight line which constantly intersects a given curve and remains parallel to itself.

   b. *A conical surface* is a curved surface generated by a straight line which constantly intersects a given curve and passes through a fixed point, called the apex.

V. Plane Figures

1. A *plane figure* is any part of a plane surface bounded by straight or curved lines.

2. A *polygon* is a plane figure bounded by straight lines.

   a. A *regular polygon* is one where the bounding straight lines are all of the same length and the angles are all equal.

   b. An *irregular polygon* is one where the bounding straight lines are of different lengths.

   c. The *sides* are the straight lines bounding the polygon.

   d. The *perimeter* is the length of all the sides added together, which is the whole distance around the figure.

   e. The *angles* of a polygon are the angles formed with each other by the bounding sides.

   f. The *base* of a polygon is the side upon which it rests.

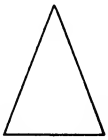
   g. The *altitude* of a polygon is the length of the straight line drawn from the highest point perpendicular to the base, or the base extended.

   h. The *diagonal* is a line which joins two vertices and does not form a side.

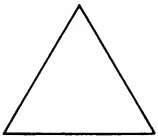
   i. *Regular polygons* are named by the number of sides as follows:

Triangle—3 sides.	Heptagon—7 sides.
Quadrilateral—4 sides.	Octagon—8 sides.
Pentagon—5 sides.	Decagon—10 sides.
Hexagon—6 sides.	Dodecagon—12 sides.

TRIANGLES

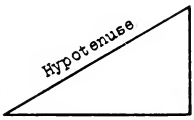


Isosceles



Equilateral

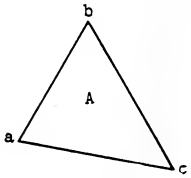
Scalene

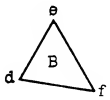


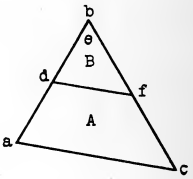
Right-Angled

Oblique

Equal



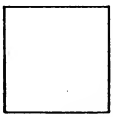




Similar or Proportional

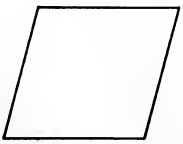
QUADRILATERALS

Rectangle

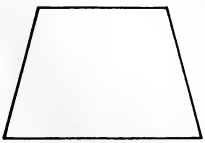


Square

Rhomboid



Rhombus



Trapezoid

Trapezium

3. A *triangle* is a polygon having three sides.

   a. An *isosceles* triangle is one having two of its sides of equal length.

   b. An *equilateral* triangle is one in which all three sides are of equal length, which makes all the angles equal.

   c. A *scalene* triangle is one in which all of the sides are of different lengths.

   d. A *right-angled* triangle is one in which one of the angles is a right angle, or has 90 degrees. The *hypotenuse* is the side opposite the right angle.

   e. An *oblique* triangle is one which has no right angle and in which no two angles are equal.

   f. *Equal* triangles are such in which the sides of one are of the same length as the corresponding sides of the other.

   g. *Similar* triangles are such in which the angles of one are the same as the corresponding angles of the other.

   h. *Proportional* triangles are similar triangles. If the side of triangle *A* is twice or any number of times the length of the corresponding side of similar triangle *B*, then all of the sides of triangle *B* are the same number of times the length of the corresponding sides of *A*.

4. A *quadrilateral* is a plane figure having four sides.

   a. A *parallelogram* is a quadrilateral whose opposite sides are parallel.

      1. A *rectangle* is a parallelogram whose angles are all right angles.

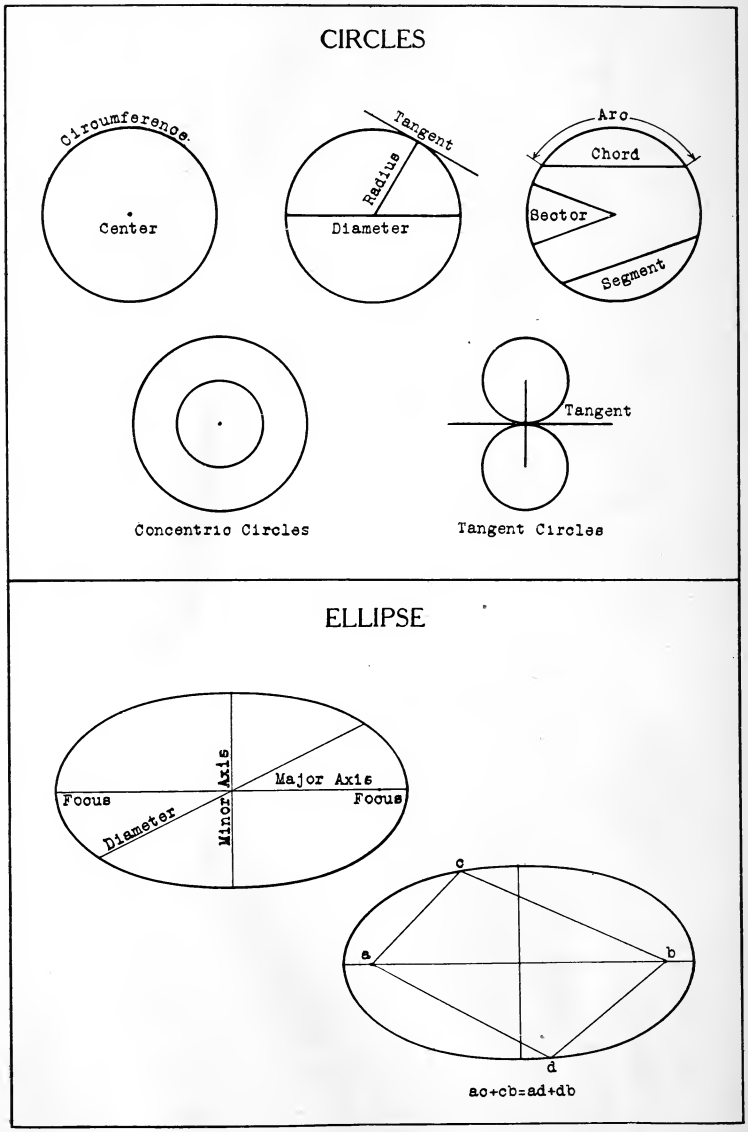
      2. A *square* is a rectangle whose sides are equal.

      3. A *rhomboid* is a parallelogram whose angles are not right angles, but whose opposite sides only are equal.

      4. A *rhombus* is a parallelogram whose angles are not right angles, but all whose sides are equal.

   b. A *trapezoid* is a quadrilateral which has only two of its sides parallel.

   c. A *trapezium* is a quadrilateral having no two sides parallel.


CIRCLES
Circumference
Center
Tangent
Radius
Diameter
Arc
Chord
Sector
Segment
Concentric Circles
Tangent
Tangent Circles
ELLIPSE
Minor Axis
Major Axis
Focus
Focus
Diameter
c
a
b
d
ac+cb=ad+db

5. A *circle* is a plane figure bounded by a curved line equi-distant at every point from the center.

a. The *diameter* is any straight line drawn through the center and terminated by the curve on each side. All diameters are of equal length.

b. The *radius* is any straight line drawn from the center and terminated by the circumference. It is one-half the length of the diameter.

c. The *circumference* is the curved line bounding the circle. Its length is called the *perimeter.*

d. An *arc* is any part of the circumference.

e. A *chord* is a straight line joining any two points on the circumference.

f. A *segment* is the area of space bounded by an arc and the chord joining its extremities.

g. A *sector* is the area or space bounded by an arc and two radii connecting its extremities with the center.

h. A *quadrant* is a sector where the radii are at right angles to each other. It is one-fourth of a circle.

i A *tangent* is a line which touches the circle at just one point of the circumference; it is always perpendicular to a radius drawn to that point. Two circles are tangent to each when they touch at just one point; a line connecting the centers passes through the point of contact.

j. *Concentric* circles are circles drawn from the same center.

k. A *semi-circle* is one-half of a full circle.

6. The *ellipse* is a plane figure bounded by a curved line such that the sum of the distances of any point on it from the two fixed points, called the foci, is always the same.

a. A *diameter* is any line drawn through the center and terminated by the ellipse.

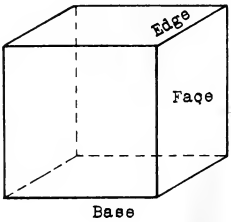
b. The *major axis* is the longest diameter. The foci are located on it.

c. The *minor axis* is the shortest diameter.

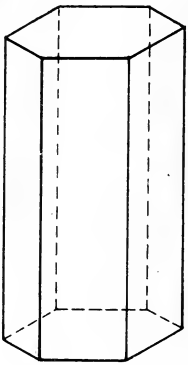
d. The *major* and *minor axis* are always perpendicular to each other.

e. Any *diameter* is divided into two equal parts by the center.

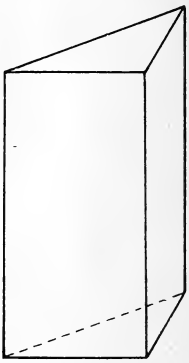
SOLID FIGURES



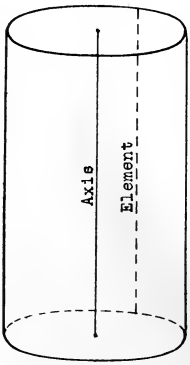
Cube



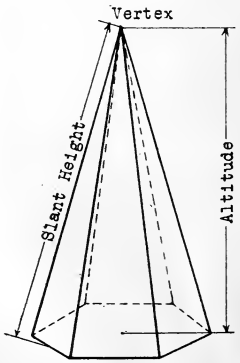
Prism



Prism



Cylinder



Pyramid

VI. Solid Figures

1. A *solid figure* is a figure which has three dimensions, length, breadth and thickness.

2. A *polyhedron* is a solid bounded by plane surfaces.

   a. The *faces* are the sides which enclose the figure.

   b. The *edges* are the intersections of the faces.

   c. The *entire surface* is the area of all the surfaces enclosing it.

   d. The *altitude* is the height of the highest point, measured perpendicular to the base.

   e. *A dihedral angle* is an angle formed by the intersection of any two faces.

   f. A *solid angle* is one formed by more than two intersecting planes passing through a common point called the *apex*.

   g. The *volume* is the space enclosed by the faces.

2. A *prism* is a polyhedron whose sides are parallelograms and whose ends are equal polygons parallel to each other.

   a. A *parallelopipedon* is a prism whose bases are parallelograms.

   b. A *cube* is a parallelopipedon whose faces and bases are squares.

3 A *cylinder* is a closed cylindrical surface intercepted by two planes which form the bases.

   a. The *axis* of a cylinder is the line connecting the centers of the curves forming the bases.

   b. The *altitude* is the perpendicular distance between the two ends.

   c. An *element* is a straignt line on the surface which coincides with any one of the positions of the generating line.

   d. A *right cylinder* is one in which the axis is perpendicular to the base.

4. A *pyramid* is a solid whose base is a polygon and whose sides are triangles uniting in a common point, called the vertex.

   a. The *altitude* of a pyramid is the height of the vertex measured perpendicular to the base.

   b. The *slant height* of a pyramid is the length of a line drawn from the vertex perpendicular to the sides of the base when these lines are all equal.

5. The *cone* is a closed conical surface intercepted by a plane.

   a. The *altitude* is the height of the vertex measured perpendicular to the base.

   b. The *slant height* is the distance from the vertex to the circumference, measured perpendicular to latter.

6. The *frustum* of a pyramid or cone is the part remaining after the top is cut off by a plane parallel to the base.

7. The *sphere* is a solid generated by a semicircle revolved about the diameter. Any point on its surface is equi-distant from the center.